EEDP-02-8
December 1988

Environmental Effects of Dredging Technical Notes

CONFINED DISPOSAL GUIDANCE FOR SMALL HYDRAULIC MAINTENANCE DREDGING PROJECTS--DESIGN PROCEDURES

PURPOSE: This note presents a simplified procedure for design of small confined disposal facilities. Applications of this procedure will be presented in a future technical note. The design approach is the same as presented in "Confined Disposal of Dredged Material," Engineer Manual (EM) 1110-2-5027 (Headquarters, US Army Corps of Engineers 1987), except that no settling tests are required. The guidance is limited to the design of areas to be used only for small one-time disposal operations. Typically, the areas are less than 10 acres in size and the disposal takes less than 20 days. This procedure does not require laboratory settling tests because the time and expense of these tests are generally not warranted for the small quantity of sediment being disposed. However, there may still be circumstances where better estimates of storage requirements and effluent quality are needed. In those cases the design procedures and settling tests presented in EM 1110-2-5027 are recommended. This technical note is not intended for use in designing larger disposal areas because the procedure may yield too large and costly a design. This design procedure is necessarily conservative to ensure adequate storage capacity and acceptable effluent suspended solids concentrations since settling data specific to the material being disposed are not used.

BACKGROUND: The US Army Corps of Engineers dredges over 482 million cu yd of sediment annually from the nation's rivers, harbors, and ship channels in response to its mission of maintaining navigable waterways. Approximately 75 percent of this material is placed in confined upland disposal sites. Therefore, the Dredged Material Research Program (DMRP), the Long-Term Effects of Dredging Operations (LEDO) Program, and the Field Verification Program (FVP) have examined settling characteristics, storage requirements, and effluent quality for a large number of upland disposal sites (Averett, Palermo, and Wade 1988) and developed procedures and guidelines for the design, operation, and management of confined disposal areas (Headquarters, US Army Corps of Engineers 1987) to meet required effluent standards and provide adequate storage volume. These procedures require sediment and water sampling, laboratory sediment characterization, and settling tests and therefore are too costly or time-consuming for small dredging projects. Consequently, a simplified design alternative, presented in this technical note, was developed using a collection of settling data from 20 series of tests on sediments from 13 different locations in place of site-specific settling data.

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Confined disposal design consists of six principal parts:

1. Collection of project data.
2. Sediment characterization.
3. Design for initial storage.
4. Design for clarification (if zone settling occurs).
5. Design for effluent quality (suspended solids concentration).
6. Weir design.

The simplified design procedure presented here uses nomographs in place of settling tests for parts 3, 4, and 5.

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Nomograph Development

Nomographs were developed for sedimentation design using data from 20 series of column settling test data conducted by the US Army Engineer Waterways Experiment Station on sediments from 13 locations. These tests were conducted and the results analyzed in accordance with the procedures outlined in Engineer Manual (EM) 1110-2-5027. Table 1 lists the sediment sites, sedimentation description, and tests performed on these materials which provided the data used in the development of the nomographs.

The nomographs were developed using a least-squares regression analysis package to establish the best-fit relationship for settling characteristics of each material. Each data set was then given equal weight in regressing the best fits to prepare the average fit used in the nomographs. The conservative fit presented in the nomographs is based on the 95-percent confidence limit about the average fit. In the nomograph for flocculent settling of the slurry (for circumstances where zone settling does not occur) the worst-case data set was substituted for the confidence limit because this limit fell greatly outside the range of the data.

Design Procedure

The approach and nomenclature used in this design procedure parallel the design procedures used in Chapter 4 of EM 1110-2-5027. However, the laboratory testing, data analysis, and calculations used in the EM design procedures

Table 1

Sediments Evaluated by Settling Column Tests

Site	Salinity ppt	Type of Settling Tested		
		Zone	Compression	Flocculent
Ashtabula Harbor (1984)	<1.0	X	X	X*
Black Rock Harbor (1982)	24.4	X	X	X*
Everett Bay (1985)	>3.0	X		X*
Hart-Miller Island (1984)	7.5		X	X*
Indiana Harbor (1979)	<1.0	X		
Indiana Harbor (1984)	<1.0		X	X**
Kings Bay (1983)	24.0		X	
Little Lake (1981)	12.5	X	X	
Mobile Harbor (1978)	17.0	X		
Mobile Harbor, sta 28 (1983)	14.0		X	X*
Mobile Harbor--Composite (1983)	15.0			X*
Norfolk Harbor-1B (1980)	15.0		X	
Norfolk Harbor-16B (1980)	15.0	X	X	
Norfolk-55 Channel (1981)	20.0	X		
Port Bienville (1981)	13.0	X	X	
Savannah Harbor (1981)	25.0	X	X	
Savannah Harbor (1983)	<1.0			X*
Yazoo River (1978)	<1.0			X**
Yazoo River (1980)	<1.0			X**
Yellow Creek (1982)	<1.0			X**

* Flocculent settling test was performed on supernatant following zone settling of the slurry.
** Flocculent settling test was performed on sediment slurry.

are replaced by nomographs. A reading of this Engineer Manual during use of this technical note may provide a better understanding of confined dredged material disposal.

Data requirements

The following data are required to use this design procedure. The data are available from field investigations, laboratory testing on sediment characterization, project-specific operational constraints and experience in dredging and disposal activities. Estimates are often available from past experience.

1. In situ sediment volume.

2. Physical characteristics of sediment.
   a. In situ sediment concentration, void ratio or water content.
   b. Specific gravity of sediment solids.
   c. Degree of saturation (100 percent for maintenance dredging).
   d. Fraction of volume that is coarse-grained.
   e. Slurry settling behavior (zone settling or flocculent settling).
3. Disposal data.
   a. Dredge pipeline size or discharge flow rate.
   b. Dredging schedule and operating hours.
   c. Influent solids concentration.
   d. Desired effluent suspended solids concentration.
   e. Maximum allowable dike height.
   f. Freeboard height.

Design for initial storage (compression settling)

Step 1--compute or estimate disposal duration. This duration can be estimated from past experience or calculated using production rates, dredging schedules, operating hours, and downtime estimates. The project length is equal to the downtime plus the volume of in situ sediment divided by the dredge production rate and the fraction of time that the dredge in producing.

Alternatively, the project length (PL) can be computed as follows:

$$PL = [V/(\overline{Q} \times 3,200)] + \text{downtime} \tag{1}$$

where V = volume of dredged material being disposed, cu yd

$$= V_i \times C_i/C_o \tag{2}$$

V_i = volume of in situ sediment to be dredged, cu yd

C_o = solids concentration of influent dredged material, g/ℓ

C_i = solids concentration of in situ sediment, g/ℓ; typically, ranges from 600 to 1,300 g/ℓ

$$= [G_s \times \gamma_w/(e_i + 1)] \tag{3a}$$

$$= 100,000 / [(100/G_s) + w_i] \tag{3b}$$

G_s = specific gravity of the sediment solids

Y_w = specific weight of water, 1,000 g/ℓ

e_i = void ratio of in situ sediment

w_i = water content of in situ sediment, percent

and where $\bar{Q}$ = daily average flow rate, cfs

$$= (v_o \times A_o \times T_o / 24) \tag{4}$$

v_o = pipeline velocity of influent dredged material, fps; typically about 15 fps

A_o = cross-sectional area of influent pipe, sq ft

T_o = hours of active disposal per day

Downtime is the estimate of the number of days that the dredge will not operate during the disposal period; it includes downtime for repairs, weather, holidays, and other scheduled off-days.

Step 2--determine site constraints. Upon determining the project duration, the initial storage volume requirement can be determined from the nomograph in Figure 1. However, the dimensions of the disposal facility cannot be assigned until constraints on the dike height or disposal area are determined. Commonly, the maximum allowable dike height is constrained by foundation conditions which limit the loads placed on the dikes without special construction practices. The disposal area is also commonly constrained by the available area.

If the maximum dike height is known, the maximum depth of initial storage is computed as follows:

$$H_{dm} = H_{dk} - H_{pd} - H_{fb} \tag{5}$$

where H_{dm} = maximum height of dredged material storage, ft

H_{dk} = maximum allowable dike height, ft

H_{pd} = average depth of ponded water, ft; generally, 2 ft

H_{fb} = height of freeboard, ft; generally, 1 to 2 ft for small sites

Step 3--use initial storage nomograph. Use the initial storage nomograph given in Figure 1 to estimate the initial storage volume requirement given the project length in days and the in situ sediment volume in thousands of cubic yards. Enter the nomograph at the value for the project duration on the length of project axis. Proceed vertically to the first turning line representing the average case (Point A on the inset in Figure 1) and then to the second turning line (Point A' for the conservative case). These turning lines represent statistical fits of the ratio of the concentration of in situ sediment to the concentration of settled dredged material or ratio of the volume of settled dredged material to the in situ volume of sediment dredged as a function of the project duration. Draw horizontal lines through these points of intersections (Points A and A') from the initial storage ratio axis (Points B and B') to the line representing the in situ volume of sediment to be dredged (Points C and C'). Then continue both lines downward to the storage volume axis to obtain a range of storage volume in acre-feet (between Points D and D') for design consideration. The precision of these values can be improved by multiplying the in situ sediment volume by the initial storage ratios obtained at the intersections of the horizontal lines and the upper vertical axis (Points B and B'), remembering that 1,000 cu yd equals 0.62 acre-ft.

The larger value for storage volume should be used if the sediment has a high solids concentration or is expected based on past experience to settle and consolidate slowly. If the sediment concentration is low or consolidates rapidly, use the lower storage volume determined from the averaging of sediments' compression settling properties. In selecting the value for use, it is important to consider the likely impacts of and solutions for underestimating or overestimating the storage volume. Underestimating can cause a reduction in depth available for ponding and freeboard, impair effluent quality, reduce the quantity of material that can be dredged, and reduce the dredge production rate to maintain acceptable effluent quality and to permit additional

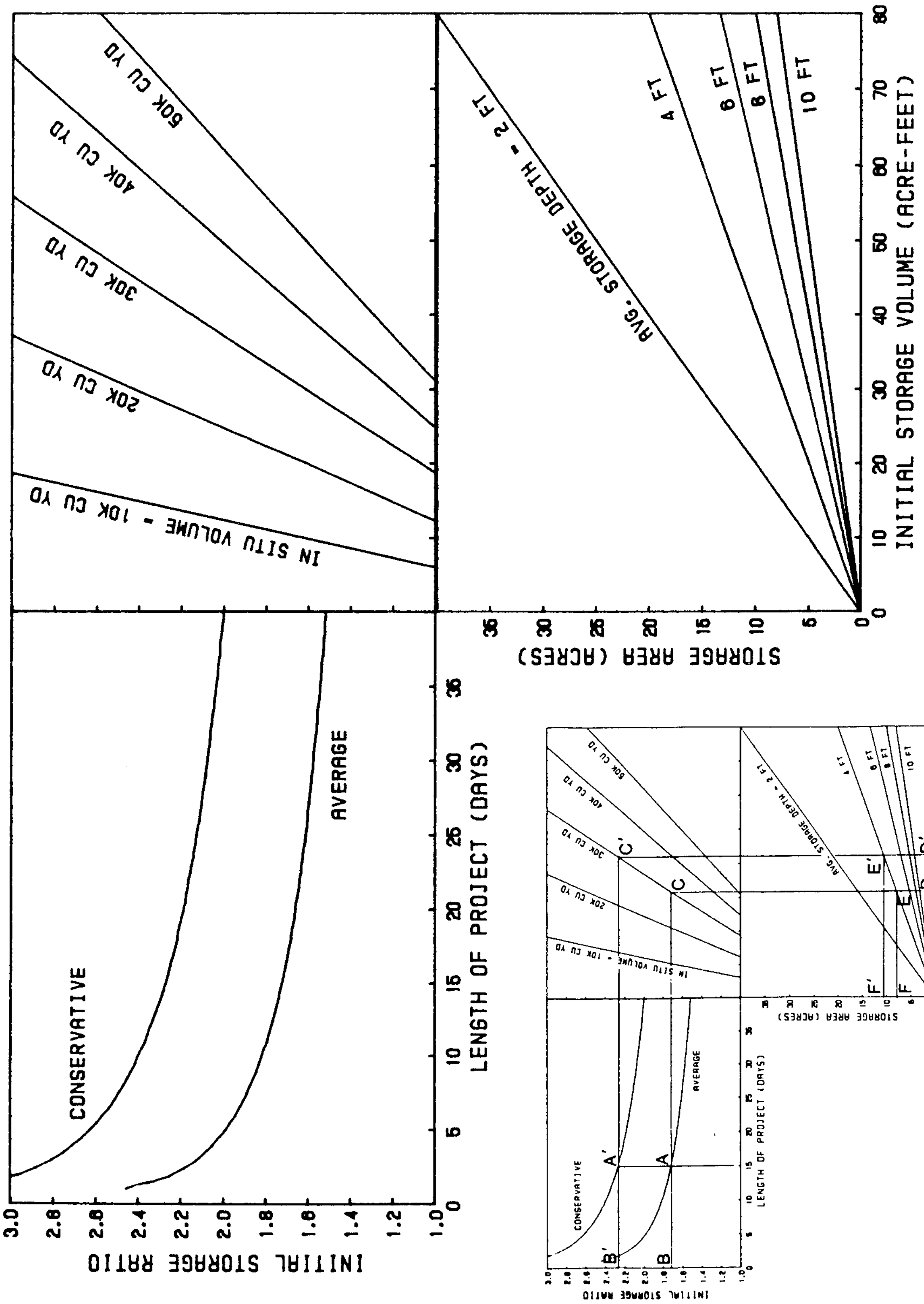

Figure 1. Nomograph to perform initial storage design of confined disposal facilities for small dredging projects using statistical fits of a compression settling data base

consolidation. Overestimating the initial storage volume unnecessarily increases the size and cost of the disposal facility, requiring more land or dike volume.

In addition to required storage volume, the nomograph can also be used to determine either the minimum area required for storage or the depth of initial storage. If the maximum allowable storage depth in feet is known from step 2 above, enter the nomograph at the value of the required initial storage volume (e.g., Points D and D') and move vertically to intersect with the line for the maximum allowable storage depth (e.g., Points E and E'). Then, draw a horizontal line to the area axis and read the value of the minimum required surface area in acres (e.g., Points F and F'). For more precision, this area could be determined by dividing the storage volume by the maximum storage depth after performing the appropriate unit conversions. Similarly, if the surface area is known, the storage depth can be computed by dividing the storage volume by the surface area after performing unit conversions. The storage depth can be read from the nomograph by drawing a horizontal line at the value of the surface area in acres (e.g., Points F and F') and a vertical line at the value of the initial storage volume in thousands of cubic yards (e.g., Points D and D') and then estimating the storage depth in feet at the point of intersection of these two lines (e.g., Points E and E').

Design for clarification (zone settling)

Slurries of most sediments undergo zone settling, particularly those slurries having a salinity greater than 3 ppt or a clay content less than 5 percent. Flocculent settling has been observed for only a few freshwater maintenance projects where the influent slurry concentrations of fine-grained solids were low (less than 80 g/ℓ). The salinity, grain size distribution, and past experience can normally be used to determine whether zone settling occurs; however, if uncertainty exists, a pilot column settling test can be performed on the simulated influent slurry in a 4-ℓ graduated cylinder to determine the settling behavior. The procedures for this determination are given in EM 1110-2-5027.

If zone settling occurs, sufficient surface area must be provided for clarification so that supernatant will be generated as rapidly as water is discharged from the disposal facility over a weir. This procedure does not determine the quality of the supernatant. Quality or suspended solids concentration is a function of residence time, not surface area. If zone

settling does not occur, then the design of the disposal facility is based on just initial storage (compression settling) and effluent quality (flocculent settling).

Step 1--selection of design data. Use of the nomograph requires knowledge of the concentration of fine-grained solids in the influent, and the average flow rate or surface area of the disposal facility. The influent solids concentration is obtained as discussed above in step 1 for initial storage design or computed in Equations 3a and 3b. The average flow rate is needed if the minimum surface area is to be computed. If the mean residence time of the disposal facility is expected to be less than half of the number of hours of active disposal per day, the average flow rate is equal to dredge discharge rate (pipeline velocity times the cross-sectional area of the pipeline). If the mean residence time is expected to be greater than half of the operating hours per day, the average flow rate should be computed by Equation 4 as described in Step 1 for initial storage design. If the surface area is known and accepted as a given, the nomograph can be used to determine the maximum allowable average flow rate.

Step 2--use clarification nomograph. The clarification nomograph given in Figure 2 is typically used to estimate the minimum surface area in acres required for clarification by zone settling given the influent solids concentration in grams per litre and the average flow rate in cubic feet per second. The procedures are illustrated in the inset on Figure 2. Start by entering the nomograph at the value of the influent solids concentration in grams per litre on the left side of the bottom axis. Proceed vertically up to the first turning line representing the average case (Point A on the inset in Figure 2) and then to the second turning line (Point A' for the conservative case). These turning lines correspond to the statistical fits of the inverse of the zone settling velocity data as a function of influent solids concentration. Draw horizontal lines from the points of intersections (Points A and A') to the line representing the average flow rate in cubic feet per second (Points B and B'). Then continue both lines downward to the surface area axis to obtain a range of surface area in acres (between Points C and C') for design consideration. The nomograph assumes a hydraulic efficiency of 0.44.

The larger surface area should be used if the sediment is known to settle slowly. Materials with high clay fractions and high plasticity indices tend to settle slower. Underestimating the required surface area reduces the

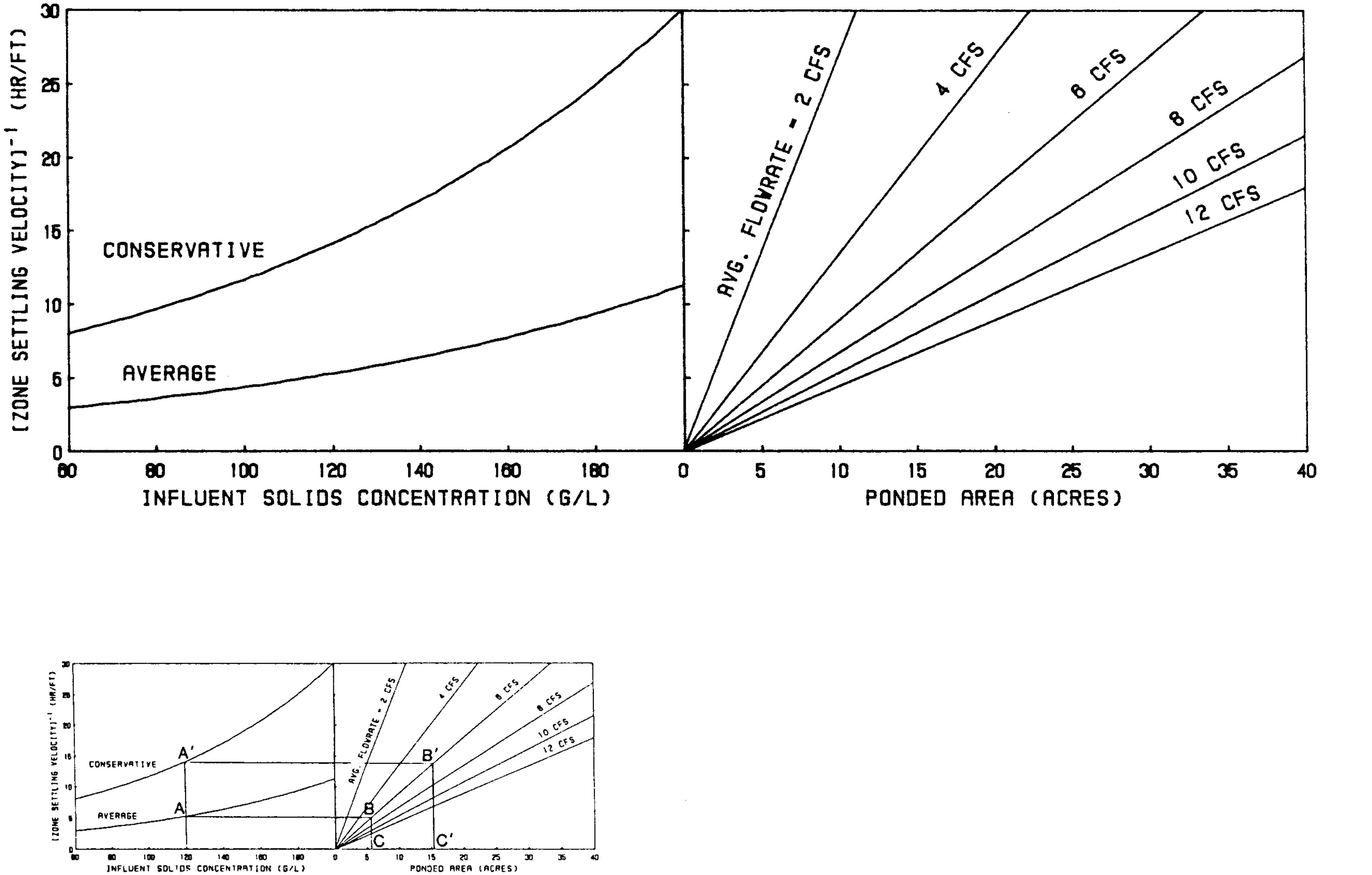

Figure 2. Nomograph to perform clarification (zone settling) design of confined disposal facilities for small dredging projects using statistical fits of a zone settling data base

allowable production rate, forcing the dredge to operate intermittently to lower the flow rate and permit clarification. Overestimating the required surface area for clarification increases the size and cost of the disposal facility.

Alternatively, the nomograph can be used to determine the maximum allowable flow rate for clarification given the surface area and the influent solids concentration. This procedure determines a range of maximum allowable flow rates for design consideration just as the above procedure yields a range of minimum surface areas. Start by drawing vertical lines at the value of the influent solids concentration in grams per litre and the value of the surface area in acres. Then draw horizontal lines at the intersections of the vertical line from the influent solids concentration with the lines for the average and conservative cases (Points A and A'). The points where these horizontal lines intersect the vertical line from the surface area axis define the range of maximum design flow rates in cubic feet per second. The lower flow rate should be used for slow settling sediments.

Design for effluent quality (flocculent settling)

Flocculent settling occurs under two different conditions--in some freshwater slurries with high clay content and in supernatants generated by zone settling of slurries. These two conditions are treated separately and a nomograph was developed for each--one for supernatants and one for slurries. However, both nomographs are identical in form and use. The nomographs assume that the depth of ponding is 2 ft. For other ponded depths the surface area axis must be adjusted by the multiplying the scale values by 2 and dividing the products by the actual ponded depth in feet. This adjustment is only approximate but should be adequate considering that the overall design approach is based on general settling trends instead of site-specific settling data. The nomographs also assume a hydraulic efficiency correction factor of 2.25 (a hydraulic efficiency of 0.44).

The development of the effluent quality nomographs assumed that the effluent quality is achieved solely by sedimentation. As can be seen in these nomographs in Figures 3 and 4, there is a practical limit to the effluent solids concentration that can be achieved solely by gravity settling, approximately 50 mg/ℓ for slurries that settle by zone settling and 2 g/ℓ for slurries that settle by flocculent settling. Better effluent quality can be achieved using chemical clarification. However, this additional treatment is

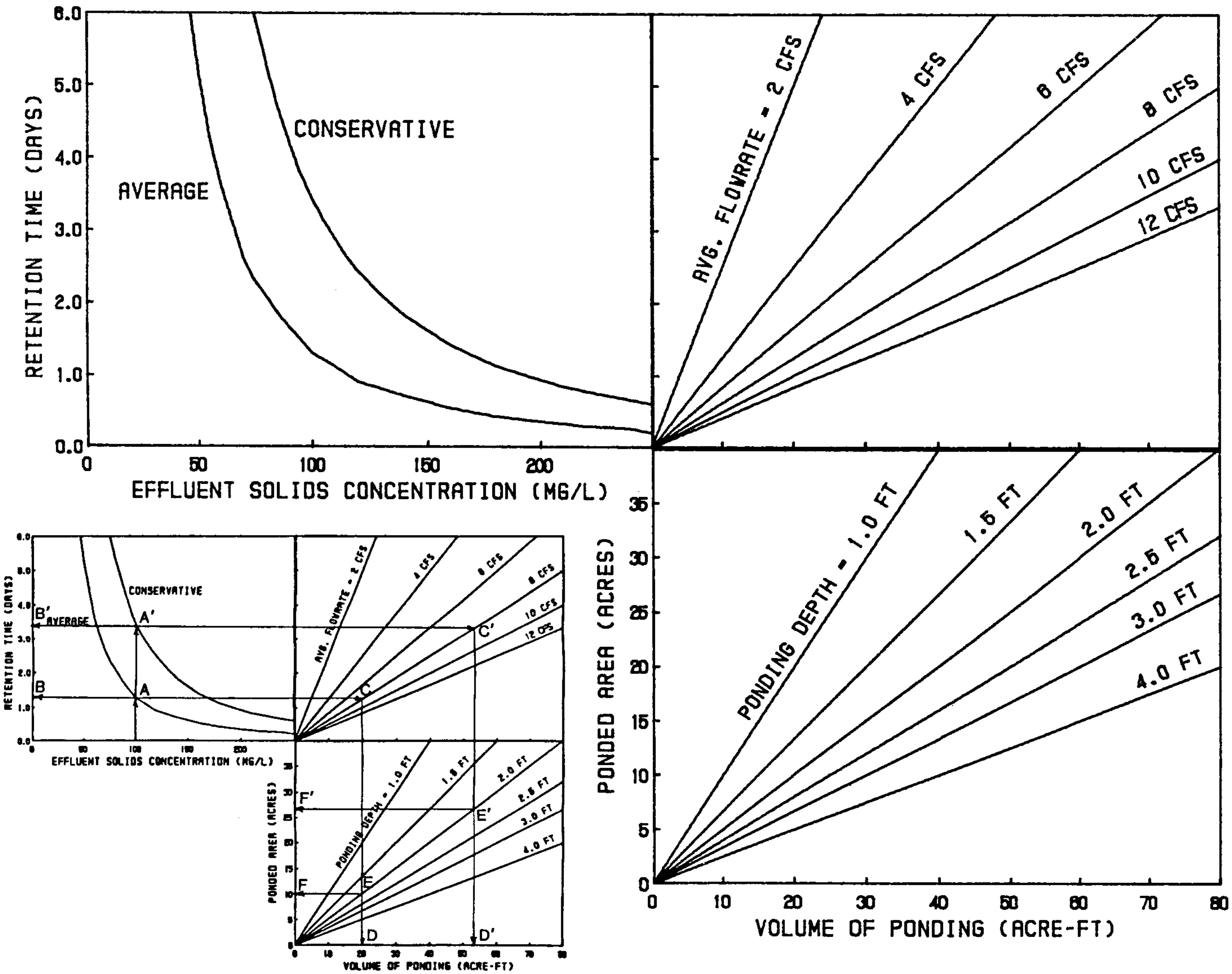

Figure 3. Effluent quality design nomograph developed for confined disposal facilities at small dredging projects using statistical fits of a flocculent settling data base for supernatants of dredged material slurries that settle by zone settling

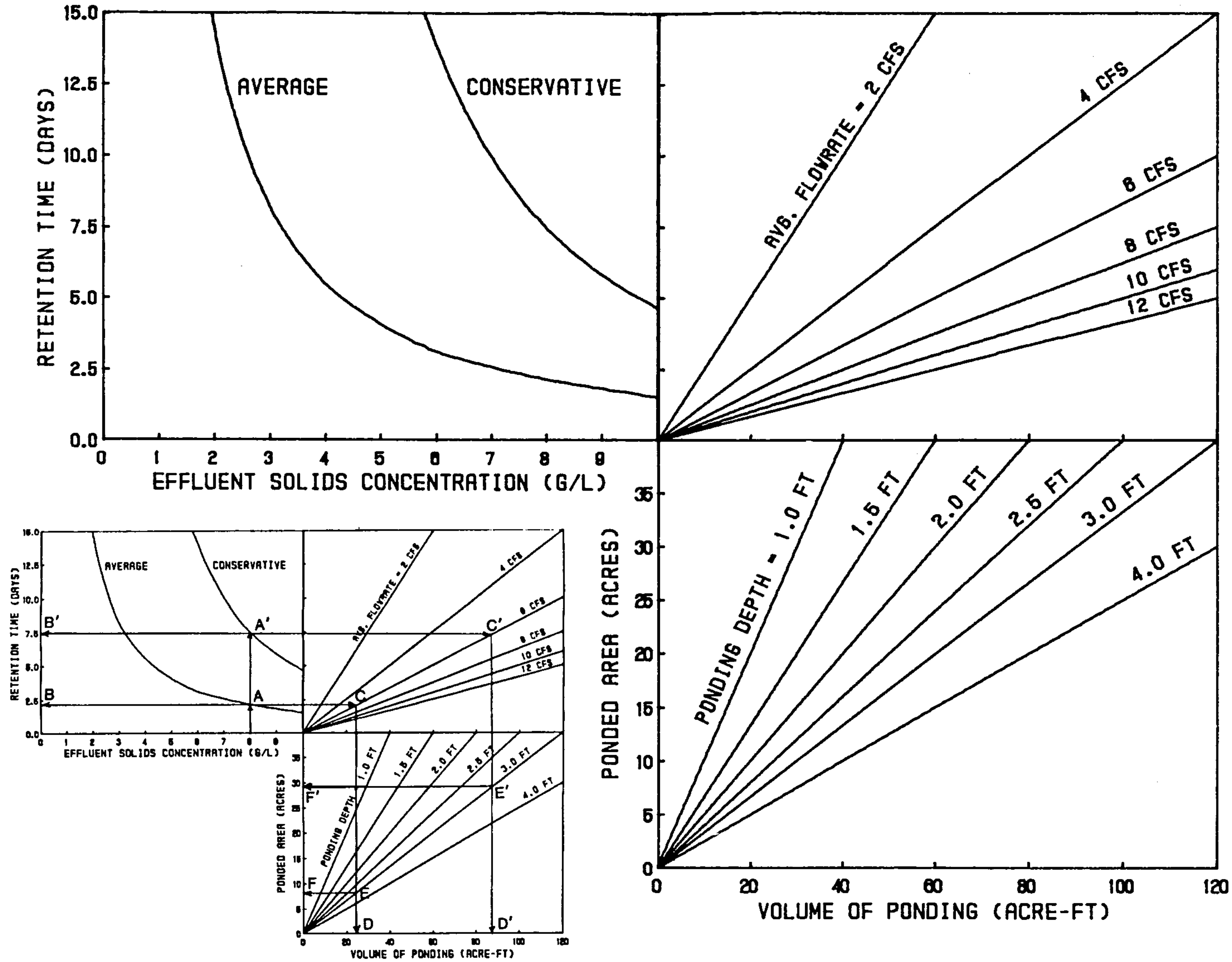

Figure 4. Effluent quality design nomograph developed for confined disposal facilities at small dredging projects using statistical fits of a flocculent settling data base for dredged material slurries that settle by flocculent settling

necessary only when the desired effluent solids concentration cannot be practically achieved considering the size of the available disposal area and the average flow rate or dredge production rate.

Step 1--selection of design data. The nomographs shown in Figures 3 and 4 can be used three ways. Typically, they would be used to estimate the minimum required surface area given the desired effluent solids concentration and the average flow rate. The selection of an average flow rate is the same as described above in step 1 for clarification design. However, the nomographs can also be used to estimate the effluent solids concentration given the surface area and average flow rate or the maximum allowable flow rate given the desired effluent solids concentration and surface area.

Step 2--use effluent quality nomograph (flocculent settling). To determine the minimum surface area, in acres, required to achieve the desired effluent quality, enter the effluent quality nomograph at the value of the desired effluent quality (in milligrams per litre on Figure 3 and in grams per litre on Figure 4) on the left side of the bottom axis. Proceed vertically up to the first turning line, representing the average case (Point A on the inset in Figures 3 and 4), and then to the second turning line (Point A' for the conservative case). These turning lines represent statistical fits of required retention time as a function of the desired effluent suspended solids concentration. Draw horizontal lines from the retention time axis (Points B and B') through these points of intersections (Points A and A') to the line representing the average flow rate in cubic feet per second (Points C and C'). The values where the horizontal lines meet the retention time axis define the design range of retention times that should be provided by ponding. Then continue both lines downward to the volume of ponding axis to obtain a range of volumes in acre-feet (between Points D and D') for design consideration. To determine the minimum required ponded area, draw horizontal lines from the points where the vertical lines for volume determination (Lines C-D and C'-D') intersect the line of the desired ponded depth (at Points E and E'), typically 2 ft, to the surface area axis. The points where the lines meet the area axis (Points F and F') define the range of minimum required surface area for achieving the desired effluent quality using the desired ponding depth.

The larger volume or area should be used if achieving the desired effluent quality is critical or if it is known from past experience with dredged material in the project area that long residence times are required to achieve

the desired effluent quality. To determine the maximum likely effluent quality when designing for average conditions, draw a vertical line downward from the point where the horizontal line for the average design conditions (the line connecting Points B and C) crosses the turning line for conservative design conditions. Then read the value where the vertical line meets the effluent solids concentration axis. As can be seen, underestimating the required surface area results in higher effluent suspended solids concentration. Overestimating the required surface area can result in higher disposal facility costs.

The nomographs can also be used to estimate the likely and maximum likely average effluent solids concentration for a disposal operation where the surface area in acres and the average flow rate in cubic feet per second are known. To determine the effluent quality, enter the nomograph at the value of the surface area in acres on the vertical axis of the lower right side of the nomograph (such as Point F). Proceed horizontally over to the line corresponding to the desired ponding depth (such as Point E). Then move vertically up to the line corresponding to the average flow rate in cubic feet per second (such as Point C). From this point of intersection draw a horizontal line to intersect the average and conservative turning lines on the left side of nomograph. At these intersection points on the turning lines, draw vertical lines downward to the effluent solids concentration axis and read the values of the likely and maximum likely average effluent solids concentration.

The maximum allowable average flow rate can also be estimated for a disposal operation where the surface area in acres and the desired effluent solids concentration are known. For these circumstances, enter the nomograph at the value of the surface area in acres on the vertical axis of the lower right side of the nomograph (such as Point D). Proceed horizontally over to the line corresponding to the desired ponding depth (such as Point E). Then move vertically up through the entire right side of the nomograph. Then, draw a vertical line up to the turning lines for the average and conservative design conditions from the value of the desired effluent solids concentration on the horizontal axis of the left side of the nomograph. Then, starting at the intersections of the vertical line and the two turning lines (Points A and A' on the inset), draw two horizontal lines to intersect with the vertical line drawn on the right side of the nomograph. The points of intersection on

this vertical line define a range of likely maximum allowable average flow rates in cubic feet per second. Overestimating the allowable flow rate results in higher effluent solids concentrations, while underestimating the allowable flow rate may unnecessarily restrict the dredging production rate.

Determination of disposal area geometry

In the three previous sections, procedures were presented to determine the minimum area required for initial storage, the minimum surface area required for clarification by zone settling, and the minimum surface area required for effluent quality when the size of the disposal facility was unknown. Ideally, all three of these area requirements should be equal to achieve the least costly facility because this would prevent the design from having greater volume for storage or effluent quality than is needed or used. In addition, facilities with smaller areas and higher dike heights are generally more economical and desirable.

Since the sizing of a disposal facility for initial storage and effluent quality is based on volume instead of area, the design procedures used a ponding depth and an estimate of the available depth for storage based on the maximum allowable dike height. Maximizing the storage depth minimizes the area required for storage; similarly, maximizing the ponding depth minimizes the surface area required for effluent quality. Since these depths are constrained by the maximum allowable dike height, trade-offs between storage depth and ponding depth can be made to more closely equate the area required for these design procedures. The minimum area required for clarification can be decreased only by decreasing the average flow rate or adding flocculents to the influent to increase the settling rate. Decreasing the average flow rate also proportionately decreases the surface area required for effluent quality and slightly decreases the area required for initial storage.

Surface area. The surface area of the disposal facility must be equal to or greater than the largest of the three minimum surface areas determined in the above procedures. If the minimum area for initial storage is much greater than the other two values, investigate the possibility of increasing the storage depth by increasing the maximum allowable dike height or decreasing the ponding depth or freeboard. Then repeat the initial storage analysis and if the ponding depth was decreased, perform the effluent quality analysis again. If the minimum area for clarification by zone settling is much greater than the other two values, consider decreasing the average flow rate or dredge

production rate (dredge size), particularly if this area is larger than the available site. After decreasing the flow rate, repeat the entire design procedure. If the minimum area for effluent quality is much greater than the other two values, examine the possibility of increasing the ponding depth by increasing the maximum allowable dike height or decreasing the storage depth or freeboard. Then repeat the effluent quality analysis and, if the storage depth was decreased, perform the initial storage design again.

After settling on a design area, compare this area with the size of the available sites. If the design area exceeds the available areas, consider a smaller flow rate or higher dikes. Also consider chemical clarification when the design is controlled by the clarification or effluent quality.

Dike height and storage depth. The height of dredged material at the conclusion of the disposal operation is computed by dividing the initial storage volume in thousands of cubic yards determined in Figure 1 by the surface area in acres. This quotient is then multipied by 0.62 to convert the result to the height of stored material in feet.

To compute the dike height, add the ponding depth and freeboard depth to the height of stored dredged material. The required ponding depth can be computed if effluent quality requirements did not control the design. The required ponding depth is computed by dividing the volume of ponding in acre-feet determined in Figure 3 or 4 by the surface area in acres. The result will be the ponded depth in feet, but the design depth normally should not be less than 2 ft except when required by design constraints. Similarly, the freeboard normally should not be less than 2 ft except when required by design constraints.

Weir design

The effective weir length required to prevent resuspension at the weir can be determined using the nomographs in Figures 5 and 6. If the slurry settles by zone settling, use the nomograph in Figure 5; if the slurry undergoes flocculent settling, use Figure 6. A discussion of these settling processes is presented above in the design section for clarification (zone settling). To use the nomograph, enter the nomograph at the value of the average flow rate in cubic feet per second on the horizontal axis. Then, proceed vertically to the line corresponding to the design depth of ponding. At the point of intersection, draw a horizontal line to the vertical axis and read the value of the required effective weir length.

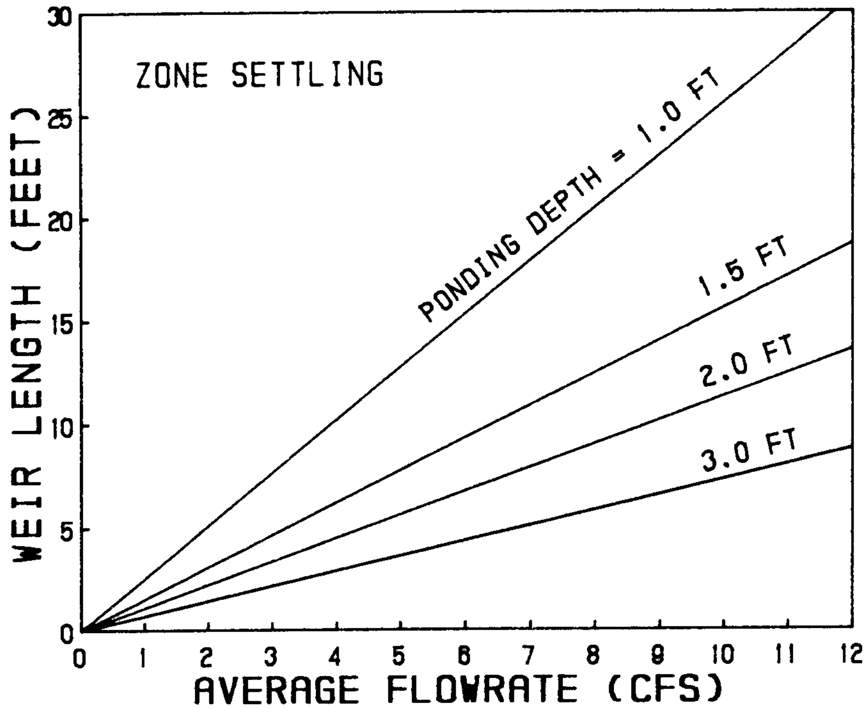

Figure 5. Weir design nomograph for confined disposal facilities receiving dredged material that settles by zone settling

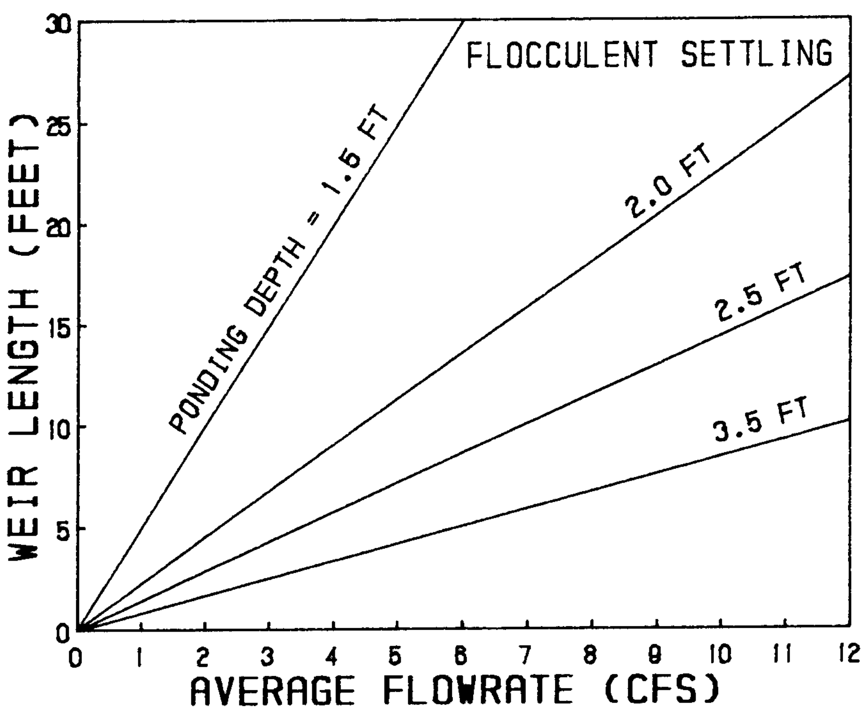

Figure 6. Weir design nomograph for confined disposal facilities receiving dredged material that settles by flocculent settling

Conclusions

The nomograph procedures presented in this technical note provide only approximate design values based on least-squares regression analyses performed on laboratory settling test data. Provision is made to separate the design for slurries that settle by flocculent settling from the design for slurries that undergo zone settling. However, aside from that distinction, all dredged materials are treated in a like manner in the nomograph design procedure. Sediment-specific properties are not used extensively; design is based mainly on general project data and the nomographs which are statistically representative of the column settling test data base for various dredging projects. These design procedures should only be used for small dredging projects where settling data are unavailable and too costly and time-consuming to obtain.

References

Averett, D. E., Palermo, M. R., and Wade, R. 1988. "Verification of Procedures for Designing Dredged Material Containment Areas for Solids Retention," Technical Report D-88-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Headquarters, US Army Corps of Engineers. 1987. "Confined Disposal of Dredged Material," Engineer Manual 1110-2-5027, Washington, DC.